Non – conventional Energy Resources
Prof. Prathap Haridoss
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture – 12

So, we looked in the last class on about a flat plate collector, and we saw what is possible in the flat plate collector in terms of gathering solar energy. As I indicated the amount of solar energy reaching our surface of our planet is about one kilo watt per meter square. Now clearly that is a sufficient for typically house hold applications where you want to raise the temperature of water to about 60 or 70 or 80 degrees centigrade and that is sufficient.

So, therefore, those are applications where you see flat plate collectors being used, you also see them being used for the food industry where may be they are trying to dry certain food items. But if you are trying to do power generation, which is a major potential application for solar energy, and if you want to use the thermal part of the solar energy, where you are not directly converting it to electricity which would be the photovoltaic approach to generating the electricity. If you are trying to use the thermal energy of the solar irradiation, and use that to generate steam and use that steam to generate electricity so that the you know existing infrastructure of turbines and expertise in those areas, can be utilized easily. Then you need to do something more in order to get this you know water to get heated to the extent of steam.

So, the basic approach to do that is to actually take sunlight that is gathered over a large surface area and then to get it to heat up the heat transfer fluid or liquid in this case water that is located in a very localized area. So, in other words a large area of sun light which then gets a captured and put in to a small area where there is water. So, that basic idea is referred to as concentration; you basically take some kind of a reflecting surface, which then takes up sun light across a wide region, aerial region and then at focuses at down to one location. And this is the way in which you can concentrate the sunlight and therefore, increase the intensity and therefore, heat up the water much more than this 80 degrees centigrade that we were seeing with flat plate collectors.

Now, clearly to concentrate sun light, you could use lenses or you could some reflecting surface. Generally the applications the demonstration of these units or the implementation of this idea in various units, they typically use only reflectors they don't use lenses. Lenses are bulky, they are difficult to handle, they can easily break etcetera. So, typically lenses are not used they use reflectors and you have two major implementations of it which can then be extended in different ways, but two major implementations are one where you have a parabolic dish.

So, a parabolic dish is a something like a bowl I means. So, it's a bowl in you know in both the x direction as well as the y direction. So, you basically have a bowl and then it focusses all the radiation down to one location. So, it's basically concave mirror, it is what you are looking at. All though in typical solar you know applications they don't use the kind of mirror that we use and say you know a physics experiment in the lab, it is not really a silvered surface there's a essentially using the highly polished stainless steel surface or a highly polished aluminum surface, that is much more robust to handle the chances that it will break are essentially not there you can of course, you know dent it in some way, but basically you are not going to break it. Whereas, if you were using glass that's a real danger that you face you can just stop it and break it, and then once it's broken its not going to function effectively for you.

So, they take metals surfaces polish them very nicely so that you have highly reflective metal surfaces, and they take the shape that you decide. So, you can do some metal working get it to the shape that you want, and that's that's also a very easy process a you just have metal forming equipment, which can then have the correct kind of dimensions and shape and then you will get a flat sheet to be shaped in the form that you want.

So, you can get well defined parabolic mirrors, that are based on a parabolic reflectors that are based on metallic surfaces, and that will help concentrate this sunlight to down to one spot. Now even though and so, if you actually go to labs and you see implementations of these solar gathering units, which are this in this concentration orient I mean idea which is using this idea of concentrating this solar radiation, what you will see is that these parabolic units. In fact, do a great job of concentrating the solar power, but you get restricted in certain ways because that location where it is getting concentrated is one specific location and. So, you have to send the water to that location it should get heated up and then it has to be removed from that location, which is the focal point of that parabolic unit or parabolic reflecting surface.

So, you have a single focal point. So, if you use this parabolic dish then you have a single focal point from which you have to take this heat away. And those parabolic dish are no different then you know the kind of dishes that you see which are used for TV antennas etcetera, but except that it is made in a very reflective form in this case.

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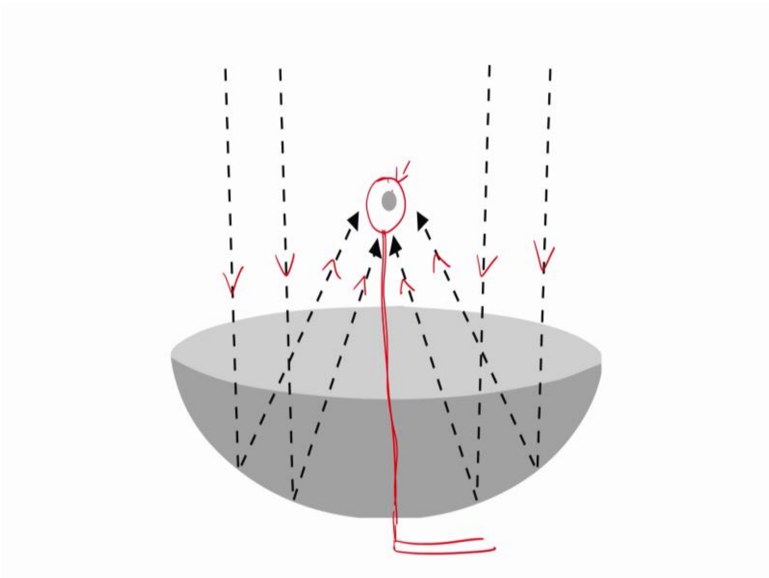

On your screen you see a parabolic dish, a parabolic dish is a way in which we are concentrating heat to a point that you see out here and basically its it is a parabola and then. So, the incoming radiation reflects of the surface of the parabola, and concentrates to the point which is its focus.

So, as long as you have a container here which at the focus, which has a tubing inside it and you are able to pick up that heat and say you can move it down in some manner down here, and take that heat out of this system and use for any other application that you want, then you have a way in which you concentrate the heat and use it for some application. So, this is concentrator that you see here and it is an imaging concentrator because it effectively forms the image of the sun at its focus may not be a perfect image, but it does essentially it is in a position to form an image.

So, that is one way in which you can do it and of course, you can think of large scale implementation of it also, where you basically have you know say several kilo meters square or say one square kilo meter of reflecting surface and then you have a tower on top of the tower you capture the heat. So, that's another implementation we will talk about it briefly towards the end of the class. What we will towards most of this class is actually one version of this heating unit, where basically the heating is done using a concentrator, but this concentrator is not a parabolic dish, but rather it it forms region which is linear and so, it is called a linear concentrator.

So, I am going to show you the parts involved in creating a linear concentrator, where you concentrate sunlight down to a line and in that line you can actually capture a lot of heat and therefore, you can flow a water through that line and then capture the heat in that water. Both the dish that I spoke about and the linear concentrator that I have just going to describe to you to begin with are called imaging contractors, because the general idea is that an image of the sun is being formed along that location and therefore, you are able to concentrate it there. In some form an image is been formed may be distorted image, but never the less an image is being formed and there are other versions of it which are also going to do concentration, but will consciously focus on not creating any image and that's called non imaging concentrator, we will talk about that towards the end of our class.

So, a non imaging concentrator does variation on this and it gives us some advantages we will talk about that towards the end of the class for most of this class we will focus on a linear concentrator, which is an imaging concentrator because in principle it is trying to form something like a image of that of the sun. Except that it is not going to be a perfect image. So, you will going to have some imperfection, and actually we benefit from the imperfection indirectly because it means that you actually have a little area of cross section, through which you can flow the water and still the heat energy that has been concentrated will effectively be captured by that water.

So, you get some little room to actually you know capture the heat and that works partly to our advantage or at least it's not a disadvantage, it works just fine. So, we will look at this implementation now, we will look at the various parts involved and I will roughly show you how it is assembled together again it will done using just our hands. So, it's not yet it’s not the exact implementation that you will see in the the lab or in a commercial setting, but it will actually work quite effectively.

A linear concentrator that has a parabolic in shape, at least in you know one dimensional is basically going to require a few different parts the first part would be the reflecting surface.

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So, for demonstration purposes here, I have a stain less steel sheet and you can see it is a reflective sheet basically it is a commercially available a stainless sheet. If you were to by a well made solar reflector it would be in much better reflective condition then this, but this is mostly for demonstration purpose, that I am going to show you what happens and. So, this is the sheet if it’s kept flat, it’s a flat plate collector and as I said our purpose here is to try to concentrate the solar energy. So, we need curve the surface. So, that it starts concentrating to one particular region.

So, basically it would be curved something like this and so now, if it has a parabolic shape.

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So, if the shape here the way it is been curved as a parabola, then it tends to focus down to a line a single line is where it will focus, and the in that to focused location you can put your heat transfer fluid. So, if you are having a situation like this where you have this parabola, and on this you are trying to do the concentration. So, you have to put a tube here at the region which is the focus of this parabola, and so, once again the correct kind of material to use for this is copper and so, you can take a copper tube you can blacken it on the outside. So, that it captures the heat very well and so that tube would then sit here In this region, which is the location which is the focus of this parabola and then.

So, this solar radiation which falls on the parabola gets concentrated on to this pipe, and therefore, the water that is following through it can become very hot. And a essentially when you do this you are able to take you know several kilo watts and put it down into the water that is following through this tube and therefore, you can get steam very easily using this kind of a concentrator. Some of the issues that I told you with respect to the flat pate collector also are valid here and one basic issue is that of course, as I said this has to be black in color, because you want it to absorb all the radiation and you also have the same situation where you can lose heat from this pipe both through convection as well as radiation, and both of these you want to prevent.

So, once again the solution is to put a glass around it, and you have to figure out what’s the good way to put a glass around it. So, that first of all the heat that is trying to escape from this copper rod is prevented from escaping, because the glass will keep that heat enclosed and it also prevents free contact of this copper rod with the air that is outside and therefore, the heat loss by convection is also lost. So, we will just see in what's the simple way for us to do it.

So, I just going to put sheet down, one simple way in which you encase this glass this copper tube is to basically have a glass tube of a slightly larger diameter, and then all you have to do is you have to put this copper tube into this glass tube.

So, now you have a copper tube sitting inside a glass tube, and it basically means that if this is exposed to solar radiation then of course, because there is glass on top again infrared is not going to go in, but more importantly the infrared that is generated by the copper that has been heated up is also not going to out. So, whatever is captured continues to remain inside it, doesn't go out and so, heat goes in it heats up the copper tube, it heats up the water inside the copper tube and then whatever temperature it reaches the heat is enable to escape that easily and continuous to remain trapped here.

So, up more complete implementation of this unit would be something like this, the copper tube in the middle in the center, you would have this glass tube around it and you would have this reflecting surface in the shape of a parabola which is then sitting like this and then heating the focusing the sun light on to this tube and therefore, you get this nice concentration that's happening, and you get a lot of heat into this tube and the process you end up generating a lot of steam, which can be used for power stations for I mean at least to heat a generator to run a generator or run a turbine, which should basically run I mean rotate a generator and generate electricity for you.

So, steam coming from here would be connected to a turbine and from the turbine you would get electricity. So, this is how concentrator a linear concentrator the major parts of a can linear concentrator would look like, and this is how they would function of course, in a more practical implementation all this would be fixed, you would have some kind of a frame which would keep this a linear concentrator in position, this tube in position you wouldn't have to hold it the way I am doing it, and also the profile of this reflector would be maintained as a perfect parabola throughout. I don't have to hold it with the hand to demonstrate it the way I am doing it here, but that is how actually implementation would like.

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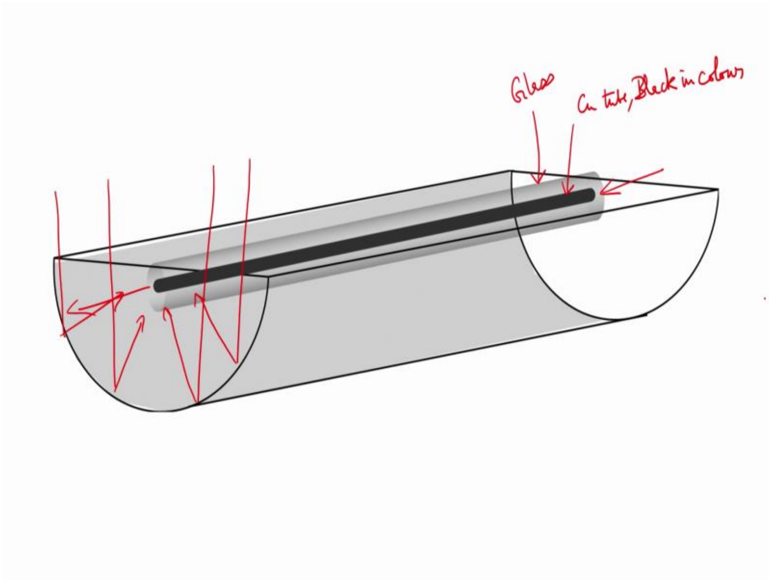

This is a parabolic trough as supposed to a parabolic dish that we previously saw. So, here it does concentration in the form of a linear concentration. So, along this line which is the tube that you see here, you have the concentration that is occurring and incoming radiation reflects of these surfaces and goes to this tube. And in that process it heats up the tube, you can again see two concentric tubes here, the inner is the black end copper tube and outer tube is glass.

The glass tube again serves the same purpose of both preventing convictive losses, and as well as preventing loss of a heat in the form of infrared radiation from that copper tube. So, this is a parabolic concentrator, it’s a called a parabolic trough based concentrator, and it helps you in significantly increase the amount of heat that is being captured by the liquids in this case water, you can easily generate steam using it.

With concentrators one of the important parameters that you have to be aware of and you have to address during an actual implementation is tracking. Basically if you look at parabolic dish and so, if you have a dish of a you know this kind of a dimension that is sitting there facing any particular direction. If you don’t track the sun then you will have a situation where the shadow of that collector unit falls on itself and therefore, a fair bit of that surface area is actually lost, you don’t actually get that for capturing solar energy.

So in fact, even that you have designed it can to capture and concentrate solar energy you are going to lose most of it, it is not going to actually capture it. So, for that to actually work well you have to get it track the sun. So, for example I have here now due east is a in that direction, west is here and then this is south and that is a north. So, if you have a parabolic dish you actually have to have it facing east during the morning, and then as the sun goes through day it has to reorient itself. So, that it is you know sort of facing upwards during the middle of the day, and then during sun set is actually facing this way.

So, that would be day log tracking. So, you would you can of course, automate it or you can do some manual way in which ever hour you come and adjust it and so, through the day this has to go from facing east to facing west that is when you really capture the sun light effectively. And then on over and above that since this is north and that is south, during the summer you can have it reasonably facing up in our kind of you know latitude, and then as this winter months begin to set you have you start orienting it downwards pointing more and more towards the south so that it tracks the arc of the sun.

So, it has to point southwards and then start this way during the morning and then slowly rotate that way towards the west during the evening. And then stay towards the southern orientation during the winter months. During the summer it can be more or less horizontal facing east in the morning, and then it tracks this way and then moves towards the west in the evening.

So, this kind of a tracking that you would need for a dish parabolic dish, that is used to concentrate the solar radiation is the referred to as the two axis tracking, because your tracking both east west and you are tracking north south and it is kind of sophisticated relatively bit expensive for you to do this, because you are trying to track across two different axis. A simple implementation of it is actually just to have a flat solar cell with a fin in the middle, and that basic that fin ensures that the solar cell of this side of the fin sees some sunlight the solar cell on the other side of the fin sees a different amount of sunlight, and then it keeps reorienting itself till that both sides of that solar cell or the two solar cells on either side of the fin are receiving the same amount of sun light.

This is a simple way in which it will track the sun, it basically reorients itself. So, that it tracks the sun such that the you know signal on both sides of that fin match up. And you can set this up and based on the dimension of this the two solar cells that you are putting on a either side, you can either have it to be analog. So, that there is difference in voltage between two of them, or you can have it such that one of them is completely dark one of them is completely lit up, and then you sort of have a digital kind of a response to the system, but this is how you would set up a tracking unit. So, right now for example, you can see that part of the right side of my palm is a little bit in shadow whereas, a left side is well lit and so, then it would have to reorient till both of them now line up, and then you will have equal sunlight on both sides of the hand.

So, this is sort of a how this one axis would be tracked and the same thing can be implemented for the other axis. So, that is how a two axis tracking work. As I said that is a little expensive to set up and especially if you have a large unit that's you know again or you have several such parabolic dish to set up in various location, then that is gets to be more expensive to do. Another way you can do it is to actually simply program in the position of the sun. Today we know enough about the astronomy of you know what we see in our skies on a daily basis, that you can actually predict the exact location of the sun on any given day on of any given month of the year, of any year infact, if you are going forward and going back ward you can say exactly where the sun was at a given point of time in the day.

So, this can be calculated it is eminently doable and we can program that into a computer, and then that would then tell the dish in which direction it should point. So, that it is directly in line with the sun this is a better system in the sense that you don't have to work about whether or not it is you know bright and sunny day the way I am facing right now or is it a cloudy day or if there is a passing cloud. In all these circumstances because you have a preprogrammed location where the parabolic dish would point, the it is guaranteed to be pointing to the sun and you are going to get the best possible result with that dish under those circumstances.

So, you have those two options; you can have a feedback control where you have the solar cell or pair of solar cells with the fin in the middle, which gives some feedback on you know which side should be a parabolic dish orient itself so that it is in line with the sun or you can have this programmed version, where you do not care about any feedback loop, you previously have fed in all the coordinates it simply points to the correct coordinate at any given point in time with the day. So, this is the way in which you do tracking and for a parabolic dish you definitely need it, because otherwise your are bound to have lot of shadow in the system and you are not going to get effective capture of sunlight.

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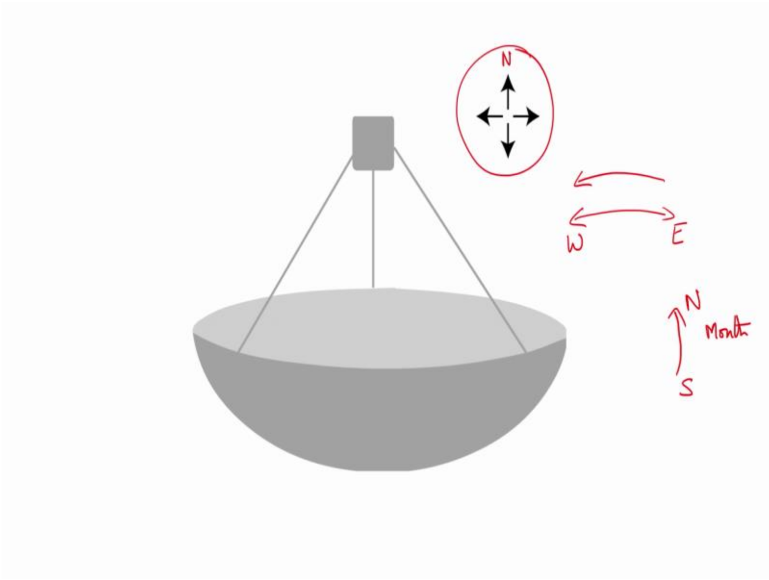

When we look at the parabolic dish we need to understand that you need to if you want it to really work effectively, it has to track the sun and so, you actually need two access tracking as I have shown you here. So, if this is north, you need it to track through day east west. So, east west tracking you have to do from east to west you will have to track through the day. So, this is how it will track facing east in the morning and then moving towards the west during the evening, at the same time for seasonal tracking you have to move from say south to north, if you are going from winter to summer. So, you have to move from south to north as you. So, this you can change every month, but this you would have to change every hour or or even better the through the day tracking.

So so, this is how you have to track you have to do a two axis tracking to really effectively utilize the capabilities of a parabolic dish collector. There is a larger scale version of this which I would talk about towards the end which is called a solar tower, which is sort extending this parabolic to something that is you know square kilometer. So, we will talk about that right at the end of the class. Now I am going to talk about how you would orient a linear concentrator, and what you know may be some aspects which make it little easier to handle the linear concentrator.

So, we will take a sheet of stainless steel again and pretend that's the linear concentrator that stimulates our linear concentrator for us for the purpose of this class, and let's see how the orientation works with respect to that okay. So, this is our flat plate collector which if I bend marginally becomes concentrator, and you can see as I oriented up and down the glare on your screen goes up and goes down, clearly indicating that you know the solar radiation is pointed in some particular direction based on how this unit is oriented.

Now, as I pointed out at the start, this is due east for me that is west, that is south and that is north. So, those are the directions we have to work with, and again you have two options possible for you; orientations possible with respect to this parabolic linear concentrator. So, I could have it set up such that it is pointed north south the way I am currently indicating it of course, you have to imagine that there is a copper tube glass encased copper tube in the middle, which is gathering up the solar energy. So, that I am not really showing it here, I am just showing you this parabolic collector and then orienting it to show you the various possibilities that exist.

So, supposing I have it pointed this way which is north south. So, north is straight ahead of me south is directly behind me. So, it is now oriented such that the axis of this collector is in the north south direction. So, if I do this for this collector to actually capture energy, it has to do a day long tracking in other words it has to point this way during the morning, and as this once this sun rises as the sun moves through the day in the sky above us, it has to reorient itself it has to keep reorienting itself all the way. So, it’s a daylong tracking, and then it has to go that way toward the end of the day and that would be a sunset situation.

So, this has to happen and. So, this is at least through the day you need this one axis tracking, and then through the seasons you still need the two axis the second axis to work. So, summary months we could have it more or less horizontal, and then during our winter this would have to be pointed this way. So, that it is pointing to more towards the south, which is where the sun is there during our winter months. So, essentially when I take this kind of linear concentrator, that is parabolic in shape in this with a using this anabolic shaped stainless steel sheet, and I use a linear contractor and I orient it north south. I effectively need two axis tracking to actually capture this sunlight effectively right.

So, it is again you know as as easy or as difficult as it is to take a complete parabola parabolic dish, and then also do the two axis tracking. So, basically it’s a question of expense, it’s a question of complexity of the system, question of worrying about you know something could go wrong and then you know you have to set it right etcetera. So, lot of those things are there, we would like to set it up such that it is easier for us to operate and is much more convenient for us to utilize.

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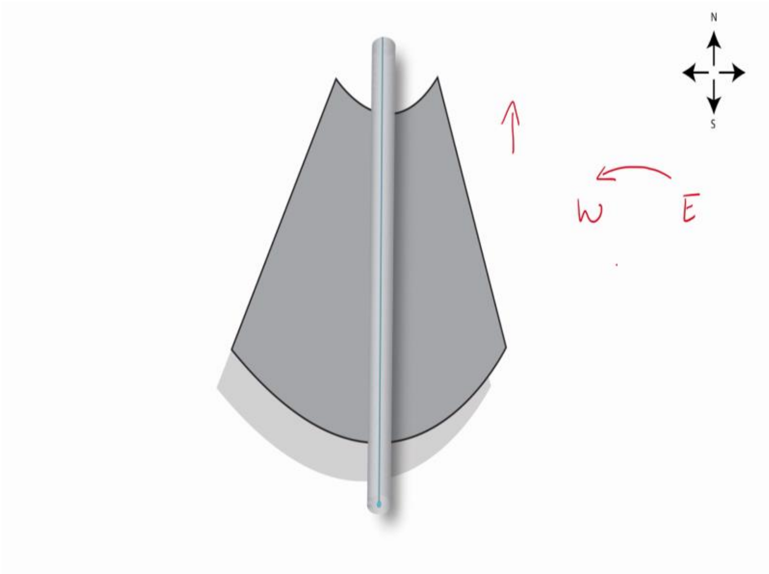

The parabolic trough can be oriented both north south as well as east west. So, I am showing you here in implementation where it is oriented north south. So, when it is oriented north south, you need it to track the sun through the day and so, again you have to if this is east and this is west, you have to get the parabolic trough to actually change its inclination through the day so that it tracks the sun. And then it’s overall inclination such that one side is lifted up needs to be done such that it phases the sun as the season changes.

So, here also you need to do some monthly change in the know inclination of this parabolic trough so that it faces the sun as based on the season. But more importantly you need to change it based on the hour of the day so that it tracks the sun as the sun moves on the on the sky in the sky through the day. So, the other orientation that we can think of for this concentrator is simple east west as supposed to north south.

So, instead of orienting the concentrator like this, I would simply orient it like this right. Instead of now being north south in orientation the axis of this concentrator is oriented east west. So, when it is oriented east west, one big advantage that we have is that we can leave in this position we don't necessarily have to track the sun, if we just leave it like this the sunlight will fall on it you are not going to have the sunlight miss this unit, but there is a one small correction that we will have to do when you set up this unit like this. Basically that copper tube that you have here the glass encased copper tube will actually have to be slightly longer than this than this reflecting surface.

The reason being during the morning when the sun is there sun light will fall here and reflect off and therefore, a some of the reflected energy is actually going to be outside the scope of this of the area defining but this concentrator and therefore, your tube should be at least this long a longer than this unit based on the height it is above it, it has to be longer than this unit. So, that the incoming radiation is fully captured by the tube.

So, on either side of this unit, the tube has to extend, longer than the length of this reflecting surface and if you as long as you just do that much you don't have to worry about the tracking of the sun during the day. You can just leave it like this sunlight will fall it will get captured by a tube starting here, going up till here and during the afternoon it will be captured by the region of the tube between here and here exactly on top of this area, and during the evening it will be captured by the region of the tube that starts somewhere here and extends out a little bit on that side.

So, if you do this much by keeping it on the east west orientation, you don't have to do day long tracking. Then the only tracking that remains is the seasonal tracking where you have to track it you know let's say roughly once a month you have to make a correction of the tracking. So, you simply have to tilt it. So, summer months you can keep it facing upwards, because the sun will be more or less directly above our head and then as the winter months come in and the sun moves towards the southern direction we have to orient it accordingly.

So, that it is now pointed relatively more towards the southern side, and then this sun light it and the sun continuous to take that arc on top and the sun light is captured by this concentrator, which concentrates down to that tube. All other aspects have to be the same and since it is only a seasonal tracking which which basically means that you have to reorient this say roughly once a month and that should be good enough for you. Technically this can be done in a manual mode also, you don't really need to do significant automation for this, you can come you can have a person or you can yourself reorient this once a month so that it is lined up roughly in with respect to the sun. So, that, for that one month it captures the heat as effectively as it can and then the next month you orient it even further south.

So, you continue this still all the way till its peak winter, and then as the sun starts coming back to us we again reoriented this reorient this back till its back up in vertical. So, this is the way in which you can do a single access tracking possibly you can do it manually with a linear concentrator, and then it becomes very convenient and it also ensures that you are able to get enough heat a concentrated in this process, that you can generate steam and therefore, you can run a turbine and generate electricity.

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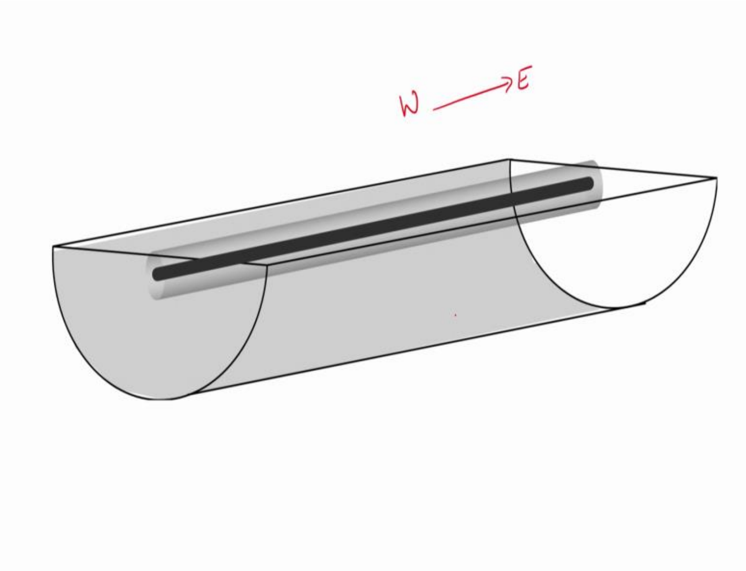

The same parabolic trough can be oriented in the east west orientation. So, if this is east and this is west, then you can set it up such that it is in this orientation and then you don’t really have to track the sun through the day, you only need to change the orientation of the overall trough by just rotating it marginally. So, that you to do seasonal tracking with respect to the position of the sun or the inclination of the sun based on the season and so, it would point little bit more towards the north during I mean or at least vertical upwards during summer, and point more towards the south during winter months.

Since we spoke about concentrators through this class, let’s consider a large scale version of it. We spoke about a small dish which concentrates sun light it is actually very nice because in you know all in two directions it is concentrating the sun light on to one spot and therefore, you get a lot of concentration effect and of course, you have the challenge of tracking tracking the sun. But supposing you want to make a large scale version of it, that just the small version which I could hold in your hand or you could hold in your hand etcetera but supposing you want to make a large scale version of it, where you want to generate several megawatts of electricity ok.

So, then what would be a way to do it? If you can think of it's like a huge parabola and in the middle you have this unit which is gathering the current. So, you can think of a tower, a tower on top of it you have a point which is the focus point and this huge parabola which in two dimensional you know in both the axis it's a parabola and then have this surface, a parabolic dish which is concentrating down to this point. So, just for I mean demonstration let us assume this tube is a tower, and this is tall tower it is a tall tower I am although I am holding this in the hand, you assume that this is a very talk lower and then you would have parabola all around it. A big parabola all around it from which sun light is getting concentrated on to this location here and then you have a lot of a heat being focused to this location.

So, that's the kind of a concentrator that we are talking about. Now we have some challenges here the first is that of course, this has to be a tall tower. So, that is say a civil engineering challenge you have to set setting up there, but then what about this reflector, how are you going to create this huge massive reflector that is there all around it so that it concentrates the heat or the sun light down to this spot. It is not feasible for you to do machining and do metal working on some sheet of metal which is say one square kilometer in dimension. So, that is not how they do it, and it is also not necessary and imagine just imagine the kind of engineering challenges that would be there if you to took something like that along with the solid tower and then try to reorient it with respect to the sun.

So, this is not how it is implemented, it is done in a somewhat different way, but it actually captures the essential concepts of how this concentrations is happening. So, to do this actually all that we need is to have a series of flat plate reflectors. So, for example, I am using this stain steel sheet here as a flat plate reflector, and then this tower would be there somewhere out of the middle, and this sheet would reflect the sun light on to the top of this tower.

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So, you can imagine that this single tower in the middle is surrounded by series of flat sheets all around, and a huge number of them semi several concentric circles of these kinds of flat sheets, and then each of them each of the flat sheet can be oriented independently.

So, you may have you know a thousands of sheets in a a in some in a circular fashion arranged around this tower, and each of those sheets can be oriented independently and in the process you can get the sunlight reflecting off of this sheet to focus on the top of the tower. And as the sun orients as the sun moves in the sky, each of the sheets independently rotates or is reoriented such that its reflection is always at the top of this tower and therefore, you have all these sheets independently oriented with respect to the position of the sun, and the focus that is on the top of this tower, and you are able to concentrate throughout the day using essentially flat sheets of metal.

So, you don’t have to worry about too much about the curvature, but the effective curvature of the overall unit is such that it is all focused on this spot, and the sheets can also actually be on the ground itself. You don’t even have to have a sheet up there, you can have a series of sheets which are on the ground which are all oriented accordingly to get to this point.

So, that’s the kind of concentrator that is used in a tower kind of a set up where you have a tower concentrator, and this kind of a concentration enables you to actually create a situation where you can get several megawatts of power being focused on this spot, and usually that tower would have a generator at the base and using that you can generate electricity. So, this is how this this larger scale version of concentration of solar energy is implemented and there are such installations around tower.

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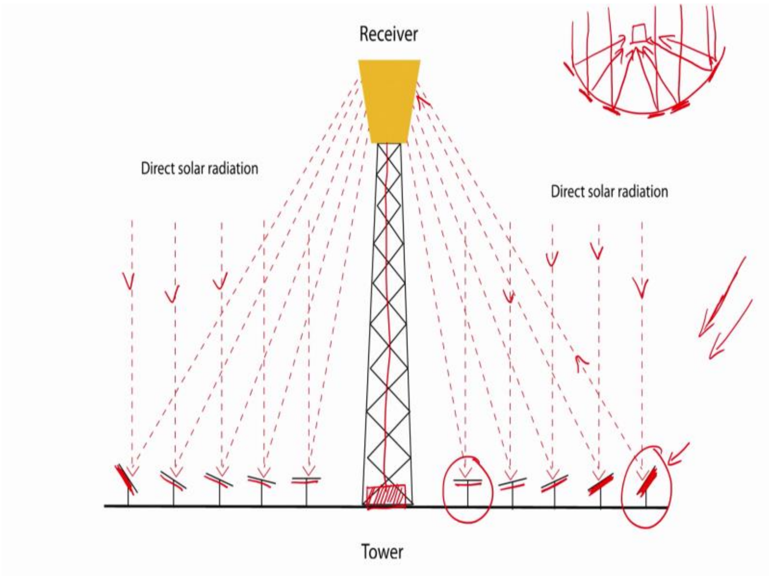

This is solar tower, basically the idea is that you know if you look at a dish you have manner in which all the energy gets captured in one location. So, you basically have a dish and you have a region where all the energy gets captured, which is what we saw when we looked at the parabolic dish concentrator. So, any incoming radiation reflects off and goes to this region, and collects at this concentrating point. But if you want to extent this to much larger region, it is not convenient to think of this as a dish, you cannot make say a square kilometer sized dish, it doesn't work its very unwilling to work with. So, instead, what you do is you actually various sections of this dish, and you place it as flat surfaces on the ground. So, that's basically what we have done. So, if we take for example, this section here you can think of it. So, it is has been here transferred, you take this section here you can think as though it is been transferred here and so on.

So, you have all these sections here, which represent the various locations on that original dish that we had up here, expect in a much more enlarged manner and then they are all placed from along the ground. You can see here the inclination of each of these is different. So, this is much more flatly oriented whereas, this is a little bit more inclined more significantly. The idea being that they are all inclined such that the incoming radiation gets reflected off of them and then all arrives at the receiver all of them arrive at the receiver and in this process the heat is concentrated with this kind of an arrangement you can set this up across you know square kilometer in area, and it would still work without any significant difficulty in actually setting it up.

So, these flat surfaces which are approximating small segments of the parabola are all basically flat sheets. So, they are flat sheets of metal which have been polished very significantly and so they are highly reflectively, and they could be fairly large reflectors they could be even reflectors the size of a room, which could be laid out on the on a floor. And each of them is programmed so that as the sun moves through the day or as the sun changes position through seasons, always the reflection each of these individual reflectors is always oriented to this receiver.

So so, based on the time of day right now you are seeing a on your screen you are seeing a situation where all the sun rays are coming vertically down and therefore, the orientations are symmetric on either side of this receiver, you find symmetrically laid out reflectors. So, what you see here is very similar to what you see here in that sense, but if the radiation where coming in a different direction in a bit inclined manner that as you can see here as the time of the day changes, then the orientations may change significantly, it may it will not be symmetric across this center receiver.

So, but again the point being they all have to reflect the radiation to the receiver, and in that process a lot of energy is stored in the receiver. And from the receiver this heat is taken straight down and you can actually have a room or some unit down here which then acts as your turbine room, and there you can you know run your turbine and generate electricity. So, that’s how this solar towers work, and they are capable of generating several tens of megawatts or even more very effectively.

They are still bit expensive due to the cost of these highly polished reflectors, but in principle its a very clean way in which you can get solar energy and conceptually also it is very easy to understand what is happening here. In principle in any desert location you can sort of think of it as some kind of a different version of a solar farm not the way the currently look at it, but in a way in its own way you can think of it as farm of some sort where you are capturing solar energy using a solar tower. Fairly high temperatures can be attained at this receiver and using that you can very effectively generate steam and run a turbine.

We spoke through this class about particular class of concentrators, which are the imaging concentrators. So, the parabolic dish that I spoke to you about, the linear concentrator that I spoke to you about, and also the tower kind of a concentrator that I spoke to you about, all of those are trying to concentrate the energy of the sun down to one spot or a very small region a line either a spot or a line. And except for the imperfection in the reflection the basic idea is to create an image of the sun at that location and therefore, essentially concentrate the energy down to that spot. There is another class of concentrators which are referred to as non imaging concentrators, because they are not focused on where the idea is not about creating the image of the sun.

So, the first three that I spoke to you about are imaging concentrates, this one is the non imaging concentrator. Its actually just a variation on the design, but it actually intelligently recreates a situation where you need not worry so much about the orientation of the sun. And the basic idea is simply this you do have two surfaces curved surfaces one is like this and there is one more you can imagine front of me there of a similar nature, and there is a flat region in the middle. So, you have this curved surface a small flat region in front of it, and another curve surface. If you have this kind of a set up and if the profile of these curved surfaces right, you create a situation that any sun light that falls in here gets reflected multiple times and then arrives at that flat surface.

So, when you have that kind of a situation you don’t have to worry so much about tracking the sun carefully. Any light that falls within this region will get will likely undergo multiple reflections, but will always go to that flat area in the middle which is the region where the heat collection is happening. So, when you do that it’s a flat region and you may have you know energy distributed across that region, but all the energy goes there and therefore, it is able to capture that energy, but it is not focused down to a line it is not focused down to a point. So, it is there is no image of the sun that is being created here.

So, this kind of a concentrator is referred to as non imaging connector and works very well in remote locations, where you don’t have the ability to go and keep changing orientation or perhaps you do not have people there to do it even manually if you wish to do it, but you still need energy with that location. So, you can set up this non imaging kind of concentrator, it will still do the job of concentrating solar energy for you and give you good performance, but of course, the imaging concentrators can focus it even better and can get you a much you know higher degree of concentration so to speak, but this would work just fine. And with without much orientation your loss is not as much in the this case of these kinds of non imaging concentrators.

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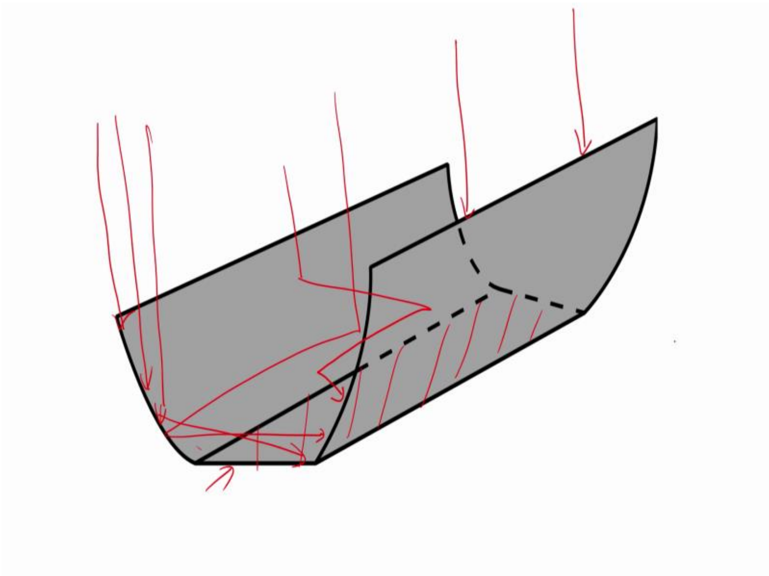

We can also consider ways of concentrating sun light, where you are not trying to form an image of the sun. So, both in the parabolic trough as well as the parabolic dish your either forming a line or you are forming a point at which the solar energy is concentrated. This is the reason why you are having to spend a lot of effort in trying to track the sun because if you don't track the sun the image will not form at the right location and you will not be able to concentrate the energy as effectively as possible.

There are ways in which you can actually sort of broaden the area over which the image is effectively being smeared out in to, and what you see here is one such version. So, the way this is set up is and so, these are called non imaging concentrators, and basically the idea is that you can set it up such that any incoming radiation sort of bounces off or reflects several times and then finally, arrives at this point. It may even bounce at bounce a few different locations. So, it may bounce this way and then come back this way etcetera, but eventually it will arrive at this bottom surface.

So, it doesn’t matter where the radiation comes as long as its sort of enters this general area, the profiles of this reflecting surfaces have been set up such that after several different you know bouncing events it will arrive at the bottom surface, and in that process the no heat is captured by the bottom surface. But since the you know the after all these reflections the light can fall anywhere in this area that you see at the bottom, this entire area that you see at the bottom, there is no specific image that is being formed of the sun anywhere and so, this is referred to as a non imaging concentrator.

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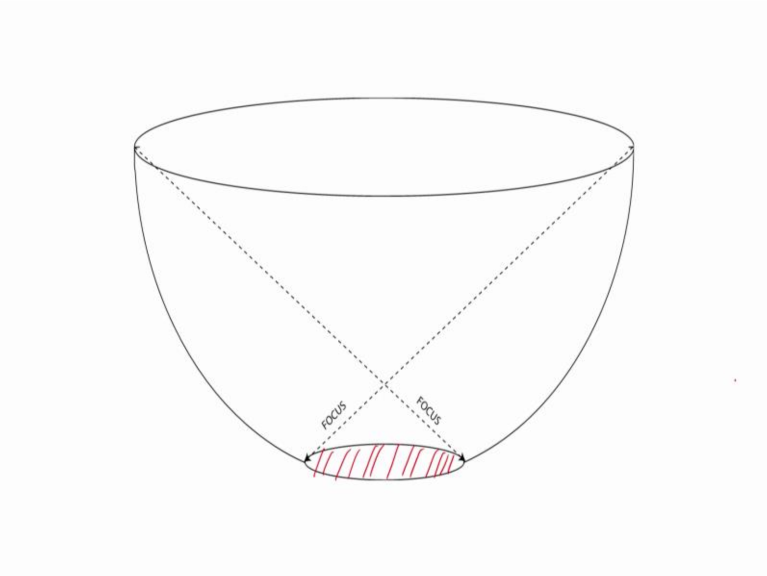

I am showing you this in the form of a trough here, you can also consider a version for it which is sort of a in the form of a dish, but this is still the non imagining concentrator, here you set it up such that the overall image could form anywhere here in a smeared sort of fashion and therefore, no there is no specific image being formed, but the energy is being captured. So, this is again a non imaging concentrator.

Thank you.

KEYWORDS:

Photovoltaic; Solar Concentration; Reflecting Surface; Reflectors; Parabolic Dish; Parabolic Mirrors; Solar gathering units; Convective Mirrors; Linear Concentrator;

Imaging Concentrator; Non – Imaging Concentrator; Parabolic Dish; Parabolic Trough; Tracking Sun; Axis Tracking; Solar Tower; Orienting Linear Concentrator; Single Axis Tracking; Double Axis Tracking

LECTURE:

Principles of Imaging Concentrators and Non – Imaging Concentrators were discussed and illustrated. Their orientation through the seasons and through a day all through the year is discussed to track the Sun and harness solar energy effectively. A large scale version of these Solar Concentrators and the set up for the same – Solar Towers are also discussed.